Adaptive contrast imaging: transmit frequency optimization

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ADAPTIVE CONTRAST IMAGING: EMITTING FREQUENCY OPTIMIZATION

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1. Introduction

The US contrast imaging domain is in full effervescence. Currently the scientific community of this field seeks US excitations which should make possible the optimization of the acoustic contrast. We tackled the problem in a simple way by proposing an adaptive imaging technique which seeks the emitting frequency which maximizes the acoustic contrast. The use of an adaptive technique is justified by the fact that :

1) during the clinical examination, the insonified medium perfused by the microbubbles is a nonstationary medium (the number of bubbles changes…),

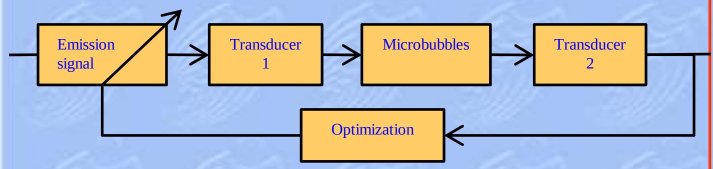
2) the pressure level is unknown because of the diffraction and attenuation effects which vary from one patient to another,

3) the size and the distribution of the microbubbles of the contrast agent are not precisely known and can differ from one sample to another.

To overcome these problems, that is to disregard these unknown factors, it seemed more judicious to propose an US excitation whose frequency is selected in an adaptive way using the technique of the gradient.

2. Methods & Materials

2.1. Methods



The signal stimulates microbubbles. Algorithm computes the frequency of the new emission signal to maximize the energy of the backscattering signal.

Optimization algorithms :

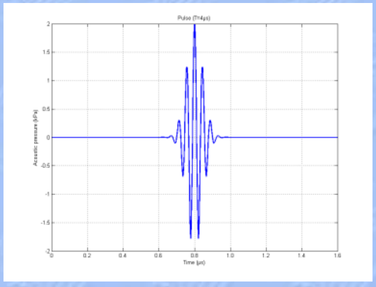
①Golden section search ρ : $\begin{cases} f_3 = f_1+\rho.\Delta f, \text{ if } E_3>E_4 \\ f_4 = f_2+\rho.\Delta f, \text{ if } E_4>E_3 \end{cases}$

with f_1 and f_2 are the initial frequencies

②Gradient ascent : steps proportional to the gradient of energy

→ $f_{k+1} = f_k+\alpha_k\nabla E(f_k)$

Wave : the length of the pulse is fixed (10 µs in experiments) → Constant emission energy



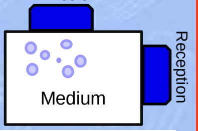
2.2 .Materials

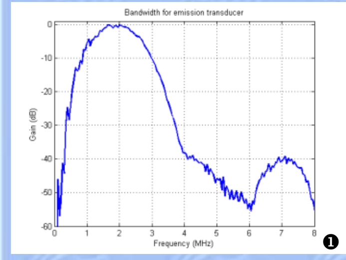
Arbitrary function generator piloted by MATLAB®

2 perpendicular transducers :

❶ Emission : 1.9 MHz – BW 80 %

❷ Reception : 3.5 MHz – BW 63%





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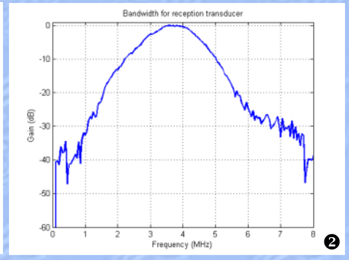

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- Compensation of bandwidth transducers with the amplitude coefficient
- Average energy on 10 reception signals to cancel the movement of the microbubbles
- Comparison with the central frequency of emission transducer
- Microbulles SonoVue™: an average of 2.5 µm-diameter and 90% have diameters less than 8 µm

Resonance frequency : f_R= 2.1 MHz

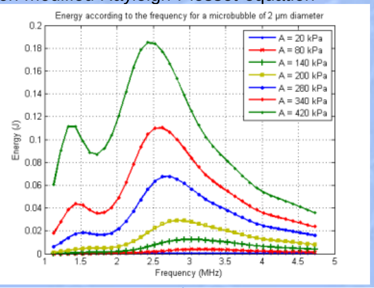
Concentration: 1/2000 diluted solution of Sonovue™

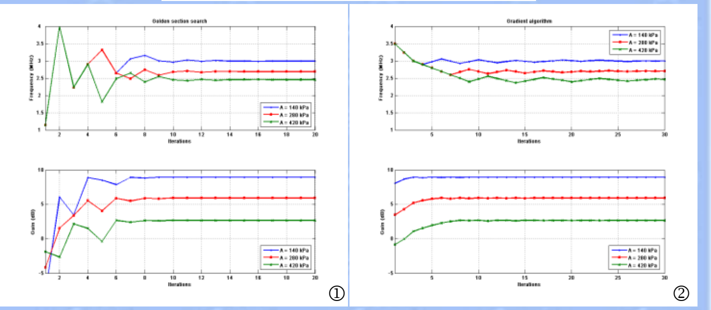
3. Results

3.1. Simulations

One microbubble :

- 2 µm of diameter
- Encapsulated
- theoretical resonance frequency f_R= 3.08 MHz
- Model based on modified Rayleigh-Plesset equation





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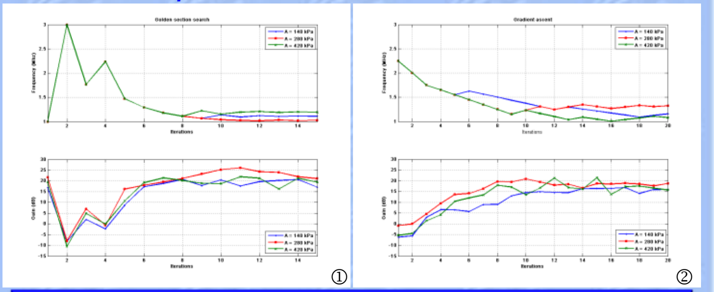
3.2 . Experiments



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4. Discussions

We show through simulations and in vitro experiments that our adaptive imaging technique gives :

1) in case of simulations, a gain which can reach 9 dB compared to the traditional technique and
2) for in vitro experiments, a gain which can reach 18 dB.

According to the pressure applied to microbubbles, the optimal frequency changes. After around ten iterations, the optimal frequency has been found and the energy of the microbubbles is stable.

In vitro, the energy is computed for a cloud of microbubbles. To cancel the movements of the cloud, we repeat the experiment. A high number of repetition and a high number of number of iterations could destroy the microbubbles and thus the energy could decrease. A trade-off must be found to avoid the destruction of the microbubbles.

4. Conclusion & future prospects

- The optimization permits to increase the backscattering energy. This gain increases the contrast.
- The optimal frequency can be very different compared to the frequency of the traditional technique.
- With the gradient algorithm, simultaneous adaptation in frequency and in amplitude.
- Adaptation with a distort sinus curve

Acknowledgement

This work was supported by Agence Nationale de la Recherche (Monither project).